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RESEARCH PAPER 28

USING FIRE-WEATHER FORECASTS and LOCAL WEATHER OBSERVATIONS in PREDICTING BURNING INDEX for INDIVIDUAL FIRE-DANGER STATIONS

by OWEN P. CRAMER

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
R. W. COWLIN, DIRECTOR
U. S. DEPARTMENT OF AGRICULTURE
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SYNOPSIS

Any agency engaged in forest-fire control needs accurate weather forecasts and systematic procedures for making the best use of predicted and reported weather information. This study explores the practicability of using several tabular and graphical aids for converting area forecasts and local observations of relative humidity and wind speed into predicted values for individual fire-danger stations. Difficulties in preparation and use of these aids by field personnel were investigated during 2 summers on 5 ranger districts in the national forests of Oregon and Washington. Emphasis was given to accuracy of predictions of changes and other situations important to fire control. Actually tested were: (1) aids for adapting area forecasts of wind speed and relative humidity, (2) a procedure for predicting wind speed, (3) aids for the use of predicted relative humidity in forecasting fuel moisture, and (4) routine statistical procedures for predicting wind speed, fuel moisture, relative humidity, and burning index class.

Performance of the various methods varied considerably between stations, depending on the complexity of the relation between station weather and the prevailing weather situation. Aids utilizing area forecasts could not, of course, correct basic forecast errors. Aids based on climatic averages would be incorrect with any departure from a normal weather situation. Difficulty of aid preparation was another serious handicap. Nevertheless, certain aids showed real promise for some stations, thus permitting more intensive use of forecasts and other weather information now available. In the course of the study, improvements were made in methods previously suggested for predicting the burning index. But, perhaps most important, the study emphasizes that much more research will be needed before fire weather and fire danger can be predicted with enough accuracy to meet adequately the needs of forest-fire control.

Grateful acknowledgment is made for the active participation and assistance of National Forest Administration, Forest Service, Region 6; particularly personnel of the Oakridge, Wind River, Naches, and Prineville Ranger Districts for preparing required aids and making field tests. The author is also indebted to Mrs. Jean Myers, W. Dale Heigh, and Roger S. Stamy for assistance in chart preparation and data analysis.

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Division of Forest Management Research

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PACIFIC NORTHWEST
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R. W. Cowlin, Director Portland, Oregon

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INTRODUCTION

In the national forests of Oregon and Washington, size and activities of the fire-control force are adjusted daily to the potential need indicated by the burning index (B.I.), which describes rate of fire spread (table 1). In Oregon and Washington national forests, B.I. is based on observed wind speed and moisture content of fuel-moisture indicator sticks during the critical burning period of the day. As the critical burning period normally occurs in midafternoon, today's protection forces have usually been determined largely by yesterday's need. A means for predicting the burning index is needed to permit adjustments in the force before the need arises.

At a meeting in 1949, fire-control administrators from Oregon and Washington national forests proposed that the protection force be adjusted to predicted burning conditions. This was to be done primarily by adapting the fire-weather forecasts, which are made for large areas, to fit individual fire-danger stations. The adaptation, or adaptive forecasting, was to be done locally by men familiar with local weather variations.

Fire research personnel at the experiment station believed that adaptive forecasting by men without meteorological training would not prove to be as simple as originally conceived. Because of differences in exposure between stations, observed weather at each station would be related in a different way to the area weather of the forecast. Some of these relations might be known to experienced men, but experienced men might not always be available. If simple and consistent relations existed between weather at the individual station and broad-scale weather described in the area forecast, these relations might be established from past records by graphical or tabular means and would then be helpful for adaptive forecasting by fire-control personnel. Possibilities were explored and methods of preparing and using the most promising estimation aids were devised for field application.[1/]

[1/] Cramer, O. P. Methods for estimating future burning index from fire-weather forecasts and local weather observations. U. S. Forest Serv. Pac. NW. Forest and Range Expt. Sta., 22 pp. (Processed.) 1950.

Table 1.--Burning index class[1/] as determined by fuel moisture and wind speed in Forest Service Region 6

Wind speed (m.p.h.)	Fuel moisture percent (summer - after July 15)													
	3	4	5	6	7	8	9	10	11	12	13-15	16-25	-	
	Burning index class													
0- 3	5	4	4	3	3	2	1	1	1	1	1	1	1	0- 3
4- 6	6	5	5	4	4	3	2	2	1	1	1	1	1	4- 6
7- 9	6	6	6	5	4	4	3	2	2	2	2/1/2	1	1	7- 9
10-12	7	7	6	6	5	5	4	3	2	2	2	2/1/2	1	10-12
13-15	8	8	7	7	6	6	5	4	3	3	2	2	2	13-15
16-18	9	9	8	8	7	6	6	5	4	3	2	2	2	16-18
19-27	10	10	9	9	8	7	7	6	5	4	3	2/2/3	2	19-27
	2	3	4	5	6	7	8	9	10	11	12	13-15	16-25	Wind speed (m.p.h.)
	Fuel moisture percent (spring - before July 15)													

[1/] Burning index is divided into 10 numerical classes.
[2/] Upper number should be used during summer; lower, during spring.

The following aids were suggested to the field:

1. A table for converting the wind prediction for an area to a speed prediction for an individual station (W-2 aid).

2. A table for converting the minimum relative humidity prediction for an area to a prediction of 4:30 p.m. humidity for an individual station.

3. A table for predicting 4:30 p.m. wind speed for a station, based on the observed 8:00 a.m. wind (W-3 aid).

4. Charts for predicting 4:30 p.m. fuel moisture for a station, based on predicted 4:30 p.m. humidity and observed 4:30 p.m. fuel moisture the previous evening (FM-p.m.) or on predicted 4:30 p.m. humidity and observed 8:00 a.m. fuel moisture the same day (FM-a.m.).

5. Normal values of 4:30 p.m. wind speed, relative humidity, fuel moisture, and burning index.

At the request of the Division of Fire Control in the regional forester's office, field tests of the resulting forecasting aids were made during the 1950 and 1951 fire seasons on five ranger districts. There were three objectives: (1) To test the feasibility of preparing and using forecasting aids in the field; (2) to learn if the forecasting aids would be more accurate than the old system of assuming that tomorrow's burning index would be the same as today's; and (3) to discover what additional research is needed. This paper will report the results of the field tests.

DESIGN OF STUDY

Coverage

The testing of methods for predicting burning-index factors (wind speed and moisture content of fuel-moisture indicator sticks) was divided into two separate studies. One dealt entirely with predictions of wind speed for individual stations by various methods.[2/] The second--reported here--deals primarily with relative humidity, fuel moisture, and burning index. Relative humidity is considered, although not used directly in computing the burning index, because a prediction of humidity is necessary for predicting fuel moisture. And as variations in procedure for predicting fuel moisture were primarily differences in the method of predicting relative humidity, humidity is considered before fuel moisture. Accuracy of wind and fuel-moisture predictions affects the accuracy of burning-index predictions.

Operational difficulties in the preparation and use of forecasting aids are also discussed. Resulting recommendations for the use of aids and for additional research will be found in the CONCLUSION.

[2/] Cramer, O. P. Test of wind predictions for peak fire-danger stations in Oregon and Washington. U. S. Forest Serv. Pac. NW. Forest and Range Expt. Sta. Res. Paper 22, 41 pp., illus. (Processed.) 1957.

Selection of Test Districts

Personnel of six ranger districts, selected by the Division of Fire Control of the regional forester's staff, agreed to test the preparation and use of proposed aids. The districts selected represented the different climatic types of the region, and personnel had demonstrated keen interest in fire-danger rating. Regular personnel were to use existing instructions[3/] with a minimum of assistance from the research group.

Preparation of Aids

A complete set of estimation aids was to have been prepared at each ranger station for the fire-danger stations on the district, to be used during the 1950 fire season (July 1 to September 15). By the end of the season, complete sets were in operation on two of the districts and partial sets on two others.

At the end of the season, all fire-danger rating records, estimation aids, and work sheets used in the preparation of aids were thoroughly checked for each fire-danger station by the research group. Many of the aids were incorrectly prepared and had to be reconstructed in the fire research office. As the most important objective of the test was to determine the practicability of correctly prepared aids for predicting fire danger, field construction of aids was abandoned. Missing aids were then constructed by fire research personnel and furnished to the field for the 1951 test. Finally, to assure compliance with the instructions, all estimates were checked and corrected when necessary. Accuracy of estimation with the aids was then determined.

Verification

The extent to which each prediction method accomplished its work was determined by verification, which is the process of comparing predicted with observed values. Although forecast accuracy was determined for all days, special attention was given to predictions of events most important to the fire-control agency--those which are most likely to have an effect on protection costs or fire losses. One such event is a change in the B. I. sufficiently great to require adjustment of the protection force. Days with unusually severe burning

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[3/] See footnote 1, page 1.

conditions are also of special importance. Accordingly, days on which these conditions occurred have been considered separately, whereas rainy days and days for which any data were missing were omitted from the study.

Forecast accomplishment may also be judged by comparing performance of the different forecasting methods. Percentage of days with correct forecasts is often compared with percentage of days on which the value of the particular variable is normal. In the wind study, for example, accuracy of spot forecasts of wind speed on the average did not exceed percentage of days with normal wind speed; i.e., did not exceed the accuracy of a normalcy forecast. Forecast accuracy may also be compared with the percentage of days on which no change has occurred from the preceding day, i.e., with the accuracy of a persistency forecast. Persistency is doubly important in this study because it represents the old official field method of predicting fire danger. It may be assumed that if forecast accuracy does not exceed normalcy and persistency forecast scores, accomplishment is negligible. An exception is the method that successfully predicts more of the important events, such as change in nonnormal values. Forecasting accuracy significantly greater than that made by persistency or normalcy forecasting is difficult to achieve. For this reason these statistical forecasts are used as standards for comparison with other methods.

Forecast accuracy is determined as the percentage of forecasts that fall within the verification limits of the value actually observed. In this study, verification limits represent a difference from the observed value great enough to cause a difference of one burning-index class. Specific verification limits are given under each factor for which forecast accuracy was determined.

Definition of Terms

Procedures used in this study require definition of the following special terms:

Change.--A change occurs when the value observed on the preceding day, considered as a forecast, falls outside the verification limits of the observed value for the current day. For example, a day on which the 4:30 p.m. wind speed shows such change from the preceding day is called a change day.

Persistency.--Persistency is the opposite of change. It means that yesterday's observation used as a forecast falls within verification limits of today's observation. The percentage of days on which this occurs is termed percentage of persistency. A forecast for tomorrow using today's observed value is a persistency forecast.

Normal and normalcy.--The 5-year summer average or median for any variable is called its normal. Observed values are classed as normal when they fall within verification limits of the 5-year average or median. The percentage of days on which normal values occur is called percentage of normalcy. And a forecast that any factor will equal the 5-year average is a normalcy forecast. A day on which the 4:30 p.m. value falls within verification limits for the 5-year average, for instance, is called a normal day.

Types of forecasts.--The following types of forecasts are considered in this study:

1. A spot forecast, prepared for a specific spot or station.

2. An area forecast, describing weather expected over a large area that, for fire-weather forecasts, may include several adjacent national forests.

3. An adapted forecast, made by adapting or localizing an area forecast to a specific locality, i.e., producing a spot or local forecast from implications of the area forecast. It is differentiated from original forecasting in that it involves quantitative adjustment of the original or guidance forecast to fit known local exposure. An adapted forecast is sometimes referred to as a localized forecast.

WIND SPEED

Testing of wind forecasts made by various methods is the subject of a separate research paper.[4/] However, wind speed is needed to compute the burning index, so it was considered in this study also. Wind speed characteristics of the stations used in this test are given in table 2.

The following scale of verification limits was used for wind speed forecasts:

[4/] See footnote 2, page 3.

Observed wind speed (miles per hour)	Allowable difference of predicted wind speed from the observed speed (miles per hour)
0 - 9	-2 to +3
10 - 15	-3 to +4
16 - 22	-4 to +5
23 - 30	-5 to +6
Above 30	-7 to +7

Results of Test of Wind-Speed Forecasting Methods

Some of the more important findings and conclusions of the wind forecasting test are as follows:

1. Selection of the best method for predicting wind speed is a separate problem for each station.

2. Forecast accuracy for all days does not indicate forecast accuracy for the most important wind events such as changes in speed from the previous day, nonnormal speeds, and speed on days of high burning index.

3. Final selection of forecast method should be based on the effect of forecasts of the important events in terms of resulting protection cost and fire loss.

4. Spot forecasts and the W-3 aid made the highest combined scores for the most important wind events.

5. For test stations as a group, the area forecast used directly was significantly inferior to all other methods. (There were exceptions at individual stations.) Differences between the other methods were not significant.

6. The persistency-normalcy mean forecast was the only method significantly more accurate for all days than the persistency forecast. (Actually, all methods except area forecasts used directly were more accurate than persistency, but the improvements were not statistically significant.) Because of comparatively high accuracy and simple preparation, the persistency-normalcy mean forecast is suited to experimental forecasting where an estimate of average accuracy is needed. It is not so well suited to routine administrative use where the forecast forms a basis for fire-control action. The

Table 2. --Characteristics of summer wind speed observed daily at time of highest burning index[1/]

National forest and station	Elevation	Average wind speed (1945-49)	Normal wind speed class	Percentage of normalcy[2/]		Percentage of Persistency[3/]	
				1950	1951	1950	1951
	Feet	M.p.h.	M.p.h.	Pct.	Pct.	Pct.	Pct.
Mt. Hood:							
Oak Grove R. S.	1,953	6	3-8	85	81	79	72
Bedford Pt.	2,500	8	5-11	-	57	-	50
Gifford Pinchot:							
Hemlock R.S.	1,110	5	2-7	-	97	-	95
Lookout Mt.	4,230	13	10-17	-	52	-	60
Willamette:							
Salmon Cr. R.S.	1,313	5	2-7	98	98	90	84
Grasshopper	5,627	4	1-6	76	-	84	-
Ochoco:							
Wildcat L.O.	5,500	3	0-5	100	98	98	94
Maury G.S.	4,400	5	2-7	95	70	90	85
Drake Butte	6,000	8	5-11	78	67	65	61
Snoqualmie:							
Naches R.S.	2,234	9	6-12	49	46	39	52
Bald Mt.	5,906	12	9-16	29	25	20	42
Timberwolf	6,435	5	2-7	38	73	51	81
Pyramid Pk.	5,723	13	10-17	74	93	67	82

[1/] The resulting normal wind speed is usually less than 1 m.p.h. greater than if 4:30 p.m. wind speed had been used, as was done in the study that resulted in the 1957 publication "Test of Wind Predictions for Peak Fire-Danger Stations in Oregon and Washington." Although the two normals are practically the same, highest-B.I. wind was used in this study because B.I. predictions should be for highest B.I.

[2/] Observed wind speed within verification limits of the 5-year-average highest-B.I. wind speed.

[3/] Observed wind speed within verification limits of the previous day's observed highest-B.I. wind speed.

persistency-normalcy mean will never predict certain important wind events such as change in speed away from normal or continuing non-normal speeds. The normalcy forecast is approximately as accurate but has similar disadvantages.

Wind-Speed Forecasts in the Test of Burning-Index Prediction

In the absence of spot-wind forecasts, normalcy forecasts of wind were used throughout the test of B.I. prediction for each station because they were available for all stations and could be expected to approximate the average accuracy of spot forecasts for the group. Resulting differences in accuracy of B.I. forecasts for important wind situations might be allowed for in the light of known differences in characteristics between spot and normalcy forecasts.

RELATIVE HUMIDITY

Moisture content of fuel-moisture indicator sticks at 4:30 p.m. is closely related to moisture content at some previous time (such as 4:30 p.m. the day before or 8 a.m. the same morning) and to the drying conditions that act on the stick's moisture during the day. These conditions are indicated to some extent by the 4:30 p.m. relative humidity. Using these relations, aids for predicting fuel moisture from either evening or morning observations and forecasts were developed. Both aids require a prediction of relative humidity expected at 4:30 p.m. for the station for which the fuel moisture is to be estimated.

The aid for forecasting relative humidity permits the adapting of predicted humidity for an extensive area to an individual station within that area. The assumption is that the average relation between 4:30 p.m. humidity at a given station and the humidity described in the fire-weather area forecast could be readily determined. To do this, observed humidity was plotted against predicted humidity for each day of the five seasons (July 1-September 15) preceding the test (fig. 1). A line was fitted by graphic means to the resulting scatter of points and a conversion table was prepared from the graph. This table was used to adapt the area forecast to the individual station.[5/]

Although this method of forecast adaptation may increase forecast accuracy at most stations, it is to be expected that such average relations will not hold under all weather conditions. Days

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[5/] See footnote 1, page 1.

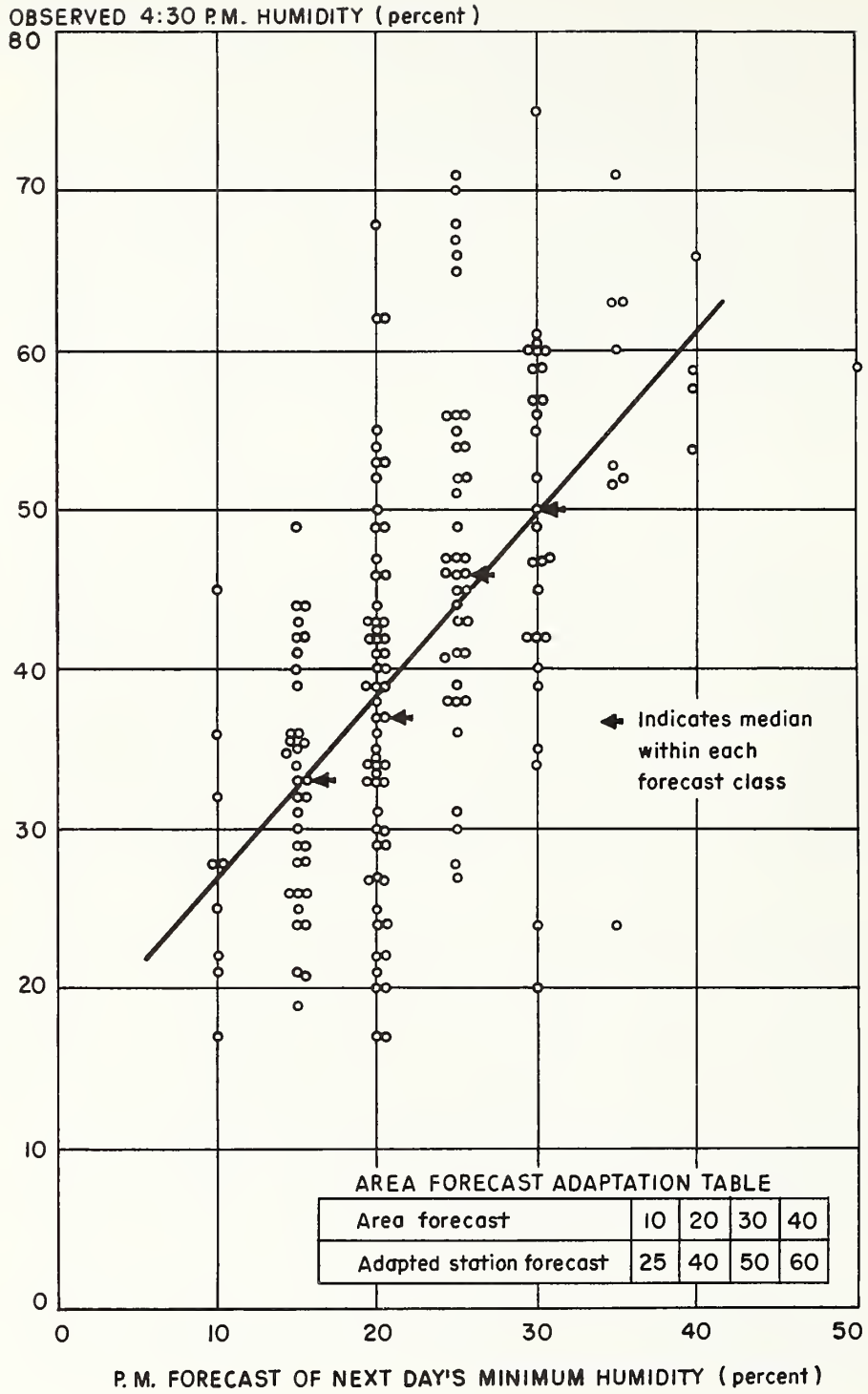

Figure 1.--Example of humidity forecast adaptation aid and worksheet.

with precipitation, for example, were omitted from the aid preparation. Other weather situations that cause a departure from the usual condition might have been studied separately, but for simplicity this was not done.

Accuracy of adapted forecasts was compared with normalcy and persistency scores for each station. Normalcy was based on the 5-year median, 4:30 p.m. summer humidity for each station (table 3).[6/]

Verification Rule

Humidity forecasts were verified by the following rule: For observed humidity 50 percent and below, the prediction had to be within 10 percent of the observed; above 50 percent humidity, the prediction had to be within 15 percent of the observed.

Results for All Days

The adaptation aid increased accuracy of humidity forecasts for most stations over the accuracy from direct use of the area forecast (table 4). The average improvement amounted to about 10 percent. Success of the aid varied greatly between stations, however; it obviously was not applicable at some stations but definitely helpful at others. In 1951, the aid was significantly more accurate for valley than for peak stations. The most striking example was at the Naches Ranger Station, where p.m. area forecasts averaged 31 percent correct for the 2 years whereas adapted forecasts were 74 percent correct.

Although the aid is an improvement, it is only slightly more accurate than the area forecast. Persistency forecasts, however, were significantly more accurate than area forecasts. Persistency averaged 8 percent higher accuracy than the adapted morning forecast.

Results for Days with Humidity Change

On the more important days when humidity changed significantly from the previous day, a persistency forecast would, of course, always be incorrect. At the test stations, the 4:30 p.m. humidity

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6/ The median was used instead of the mean because occurrence of 100 percent humidities at some high-altitude stations results in a mean too high to be representative of 4:30 p.m. relative humidity during normal fire weather.

Table 3. --Characteristics of summer relative humidity at test stations at 4:30 p.m.

National forest and station	Median 4:30 p.m. relative humidity (1945-49)	Normal humidity class	Days with below 51% relative humidity (4:30 p.m.)--proportion of all days		Percentage of normalcy[1]		Percentage of Persistency[2]	
			1950	1951	1950	1951	1950	1951
	Percent	Percent	Percent					
Mt. Hood:								
Oak Grove R.S.	42	32-57	71	82	76	58	67	80
Bedford Pt.	52	42-67	-	57	-	52	-	59
Gifford Pinchot:								
Hemlock R.S.	53	43-68	-	74	-	38	-	66
Lookout Mt.	65	51-80	-	38	-	54	-	64
Willamette:								
Salmon Cr. R.S.	37	27-47	93	96	64	49	81	84
Grasshopper	62	51-77	38	-	62	-	81	-
Ochoco:								
Wildcat L.O.	35	25-45	90	95	77	67	75	81
Maury G.S.	27	17-37	97	97	83	88	67	76
Drake Butte	32	22-42	94	96	72	48	71	77
Snoqualmie:								
Naches R.S.	42	32-57	86	88	55	59	76	77
Bald Mt.	57	47-72	36	78	47	22	66	75
Timberwolf	62	51-77	47	73	44	23	76	64
Pyramid Pk.	62	51-77	42	45	53	45	77	82

[1] Observed 4:30 p.m. humidity within verification limits of the 5-year summer median, 4:30 p.m. humidity.

[2] Observed 4:30 p.m. humidity within verification limits of the previous day's observed 4:30 p.m. humidity.

changed every fourth day on the average. Adaptation of the area forecast improved predictions, on the average, for change days in 1950 but not in 1951. On such days in 1950, the adapted p.m. forecast was the most accurate method for two-thirds of the stations, but in 1951 this method was superior for only 1 of 11 stations. Average station scores for each method for days when humidity changed are shown in table 5.

Table 4. --Accuracy of predictions of 4:30 p.m. relative humidity, for all days

(Percent correct)

Forecast method	Average, all stations		Average of selected stations (1951)[3]			
	1950[1]	1951[2]	7 peak	5 valley	7 east side[4]	5 west side[5]
Evening:						
Area forecast	55	55	51	60	49	63
Adapted area forecast	64	65	58	73	66	63
Morning:						
Area forecast	58	61	59	64	56	67
Adapted area forecast	66	66	57	78	67	64
Persistency	74	74	72	77	76	71
Normalcy	65	50	44	58	50	50

[1] Based on 10 stations.
[2] Based on 12 stations.
[3] An analysis according to station location was not made for the 1950 records. The peak and valley stations in the 1951 analysis include east side and west side stations.
[4] East of the summit of the Cascade Range.
[5] West of the summit of the Cascade Range.

Table 5. --Accuracy of predictions of 4:30 p.m. relative humidity on days when relative humidity changed from the previous day

(Percent correct)

Forecast method	Average, all stations			Peak stations[1]	Valley stations[2]
	1950	1951	Both years		
Evening:					
Area forecast	41	46	44	38	51
Adapted area forecast	58	46	51	45	58
Morning:					
Area forecast	36	52	46	45	46
Adapted area forecast	54	49	51	44	59
Normalcy	52	39	45	39	52

[1] Based on 5 stations in 1950 and 6 stations in 1951.
[2] Based on 4 stations in 1950 and 5 stations in 1951.

Results for Days with Fuel-Moisture Change

As relative humidity is used in estimating fuel moisture, and days when the fuel moisture changes from the preceding day are highly important, humidity predictions for fuel-moisture change days were also studied separately. At the test stations, fuel-moisture changes occurred, on the average, every fifth day. Average accuracies of humidity forecasts for days when the fuel moisture changed are as follows:

Forecast method	Percentage of forecasts correct	
	1950	1951
Evening predictions:		
Area humidity forecast	50	46
Adapted area forecast	60	51
Morning predictions:		
Area humidity forecast	52	56
Adapted area forecast	60	54
Persistency	45	50
Normalcy	60	54

Although no best method of humidity prediction is indicated for this group, the adapted forecasts are as accurate as any.

FUEL MOISTURE

Like wind speed and relative humidity, the moisture content of fuel-moisture indicator sticks changes from day to day and from day to night. Without rain, the diurnal fluctuation of fuel moisture is governed largely by diurnal values of relative humidity. Fuel moisture at 4:30 p.m. is most closely related to 4:30 p.m. relative humidity. Two aids for predicting fuel moisture were tested (fig. 2). One was called the FM-p.m. chart, and the other the FM-a.m. chart. The FM-p.m. used today's observed 4:30 p.m. fuel moisture and the relative humidity predicted for 4:30 p.m. tomorrow to predict tomorrow's 4:30 p.m. fuel moisture. The FM-a.m. used today's observed 8 a.m. fuel moisture and the relative humidity predicted for 4:30 p.m. today to predict today's 4:30 p.m. fuel moisture.

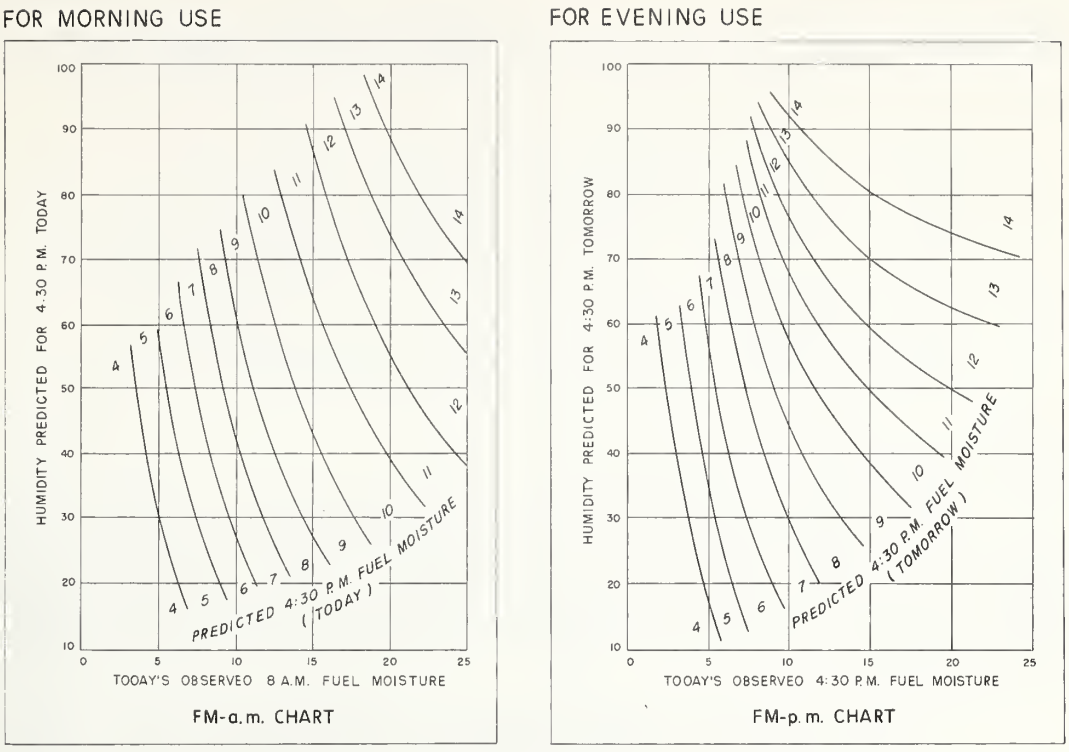

Figure 2.--Fuel-moisture estimation aids for a sample peak station.

Both aids were to be prepared by field personnel, based on measured humidities and fuel moistures for the 5 previous seasons. For simplicity in both preparation and use, no provision was made for special weather conditions that would bring a deviation from the normal fuel moisture-relative humidity relation. Additional accuracy probably would have resulted from such refinement.

Verification limits

Verification limits of fuel-stick moisture content by weight were set up as follows:

Observed moisture content (percent)	Allowable difference of predicted fuel moisture from the observed (percent)
0-8	±1
9	-1 to +2
10	-1 to +3
11	-1 to +4
12	-2 to +5
13	-3 to +6
Etc.	

Nature of the Test

Predictions of fuel moisture were made using several types of humidity predictions to check dependence of the fuel-moisture aid on accuracy of relative humidity predictions. Only in this way could inherent errors in the aid be separated from errors in the humidity forecasts used.

Characteristics of fuel moisture observations at test fire-danger stations are shown in table 6. Normalcy and persistency scores have been computed for two purposes: (1) To show amount of day-to-day and year-to-year variation in 4:30 p.m. fuel moisture, and (2) to serve as a base with which to compare accuracy of the prediction aids under test. At most stations there were fewer days with normal fuel moistures in 1951 than in 1950, particularly at peak stations. Normalcy was less than persistency at all stations in both seasons.

Results for All Days

There was no general improvement in accuracy of predictions for all days over the former official procedure of assuming persisting fuel moisture (table 7). The persistency forecast was approximately as accurate as any p.m. method; at valley stations it was also as good as any a.m. method. At peak stations, however, the a.m. fuel moisture aid had a slight advantage over other methods when used with either the area humidity forecast or persisting relative humidity.

Accuracy differences between humidity forecasting methods had variable effect on accuracy of fuel moisture forecasts. At valley stations, for example, where adapting the area forecast to the station increased the accuracy of humidity forecasts over 10 percent; fuel-

Table 6.--Characteristics of summer fuel moisture at test stations at 4:30 p.m.

National forest and station	Median 4:30 p.m. fuel moisture (1945-49)	Normal fuel moisture class	Days with below 10% fuel moisture (4:30 p.m.)--proportion of all days.		Percentage of normalcy[1]		Percentage of Persistency[2]	
			1950	1951	1950	1951	1950	1951
	Percent[3]	Percent	----------	----------	Percent	----------	----------	----------
Mt. Hood:								
Oak Grove R.S.	8	7-9	81	97	64	43	73	77
Bedford Pt.	9	8-10	-	72	-	41	-	61
Gifford Pinchot:								
Hemlock R.S.	8	7-9	-	88	-	62	-	79
Lookout Mt.	9	8-10	-	74	-	28	-	68
Willamette:								
Salmon Cr. R.S.	6	5-7	98	96	74	86	86	91
Grasshopper	8	7-9	86	-	59	-	73	-
Ochoco:								
Wildcat L.O.	7	6-8	96	98	79	19	88	78
Maury G.S.	6	5-7	96	94	84	79	85	94
Drake Butte	7	6-8	92	94	48	32	80	87
Snoqualmie:								
Naches R.S.	8	7-9	91	94	62	56	80	90
Bald Mt.	9	8-10	69	91	37	34	67	85
Timberwolf	9	8-10	69	52	51	40	69	87
Pyramid Pk.	12	10-22	39	77	60	25	84	77

[1] Observed 4:30 p.m. fuel moisture within verification limits of 5-year summer median, 4:30 p.m. fuel moisture.

[2] Observed 4:30 p.m. fuel moisture within verification limits of previous day's observed highest-B.I. fuel moisture.

[3] Fuel-moisture content is expressed as a percentage of oven-dry weight of standard fuel moisture sticks (100-gram, half-inch ponderosa pine cylinders).

moisture predictions were no more accurate when made with adapted humidity forecasts than with area forecasts. In contrast at peak stations, where persisting humidity has been the most accurate humidity forecast, it resulted in highest fuel-moisture forecast score when used with the FM-a.m. chart.

Table 7.--Accuracy of predictions of 4:30 p.m. fuel moisture, for all days

(Percent correct)

Method	Peak stations (13 station-yrs., 668 forecasts)	Valley stations (9 station-yrs., 535 forecasts)	All stations
Predictions made in evening using individual station FM-p.m. chart and:			
Area forecast relative humidity	74	84	78
Adapted area forecast relative humidity	75	87	82
Median 4:30 p.m. relative humidity	76	84	79
Persistency of previous day's 4:30 p.m. relative humidity	80	83	81
Predictions made in morning using individual station FM-a.m. chart and:			
Area forecast relative humidity	84	84	84
Adapted area forecast relative humidity	76	82	79
Median 4:30 p.m. relative humidity	79	76	77
Persistency of previous day's 4:30 p.m. relative humidity	84	81	82
Normalcy--median 4:30 p.m. fuel moisture	41	67	52
Persistency--previous day's 4:30 p.m. fuel moisture	78	85	80

There was some evidence of difference in characteristics of fuel moistures at valley and peak stations. Both normalcy and persistency scored higher at valley stations than at peaks. Assumption of persistence of fuel moisture was as accurate as any forecast for valley stations, but use of the aid with area or persisting relative humidity forecasts was slightly more

accurate in the morning at peak stations. Lack of a clearly defined best method for either peak or valley stations indicates that final selection of a method for predicting fuel moisture should be a separate process for each station.

Results for Days with Fuel-Moisture Change

On days when fuel moisture changed from the preceding day (approximately 20 percent of all days), no evening forecast method was consistently more accurate than a normalcy forecast (table 8). Furthermore, no evening method produced a high enough average verification score to be considered accurate.

Statistical comparison between evening and morning predictions of fuel-moisture changes showed that the latter were significantly more accurate at peak stations but only slightly more accurate at valley stations. Although no single morning method is clearly superior, both area and adapted humidity forecasts resulted in greater accuracy than persisting humidity.

Causes of change in fuel moisture.--Because of the poor accuracy of predictions of fuel-moisture change, cause of change was investigated. The following results were obtained:

Cause of change in 4:30 p.m. fuel moisture	Number of days with change in F.M.		Percentage of total F.M. change cases
	1950	1951	
Change in 4:30 p.m. relative humidity	24	37	30
Unusual nighttime recovery of moisture	30	57	35
Drying out from preceding rainy period--rapid decrease in both relative humidity and fuel moisture from high values	5	21	17
Possible precipitation	17	3	4
Other (temperature and unknown)	14	19	14
Total			100

Table 8.--Accuracy of predictions of 4:30 p.m. fuel moistures on days when fuel moisture changed from the previous day

(Percent correct)

Method	Peak stations (13 station-yrs., 154 forecasts)	Valley stations (9 station-yrs., 95 forecasts)	All stations
Predictions made in evening using individual station FM-p.m. chart and:			
Area forecast relative humidity	46	45	46
Adapted area forecast relative humidity	48	43	46
Median 4:30 p.m. relative humidity	40	51	44
Persistency of previous day's 4:30 p.m. relative humidity	37	34	37
Predictions made in morning using individual station FM-a.m. chart and:			
Area forecast relative humidity	70	55	64
Adapted area forecast relative humidity	71	57	65
Median 4:30 p.m. relative humidity	67	53	61
Persistency of previous day's 4:30 p.m. relative humidity	68	46	60
Normalcy--median 4:30 p.m. fuel moisture	47	48	48

Correct prediction of some 47 percent of the changes in fuel moisture depends directly on correct prediction of changes in relative humidity. Although forecast accuracy was nearly 60 percent for all humidity-change cases, accuracy for humidity changes that resulted in fuel-moisture changes was only 25 percent in the evening and 43 percent in the morning. Obviously, for this group of fuel-moisture changes, correct prediction awaits improved humidity forecasts.

For the 35 percent of fuel-moisture changes due primarily to greater- or less-than-normal nighttime recovery, a correct humidity

forecast could not be expected to produce a correct fuel-moisture prediction. For this group, factors other than humidity would dominate. The FM-a.m. chart, however, automatically takes changes in nighttime recovery into account in the morning estimate. As a result, the FM-a.m. chart shows about 20 percent greater accuracy in predicting fuel-moisture changes.

The remaining 18 percent of fuel moisture changes are apparently dominated by weather factors not covered directly by the estimating method tested here. Greater attention to such factors as high temperature, precipitation, and radiational conditions might be necessary for better accuracy in this group.

BURNING INDEX

The effect of accuracy of humidity, wind speed, and fuel-moisture forecasts on the fire-control agency is reflected in the accuracy of the resulting predictions of burning index. Forecasts used for predicting B.I. were normalcy for wind, and the FM aid with adapted relative humidity forecasts for fuel moisture. The normal (median) B.I. class for each station used in this test, together with normalcy and persistency scores for B.I. class, are indicated in table 9. Normalcy and persistency as well as forecast accuracy were figured on the basis of verification if the estimate was within one class of observed B.I.

Results for All Days

Considering all days, p.m. predictions of B.I. class were approximately as accurate as a.m. predictions (table 10) and persistency forecasts of B.I. class as accurate as evening forecasts. A normalcy forecast using median B.I. class was less accurate than the other methods. Although varying somewhat between stations, these relations held for the four groupings of peak stations, valley stations, east side stations, and west side stations.

Results for Change Days

The most important days have again been considered separately. For the days with a change in B.I. class from the preceding day (one-fourth of all days), the morning estimate was slightly more accurate in only one of the two years. Days with B.I. class 5 and higher comprised an average of 40 percent of the fire season at the test stations. A change of two or more B.I. classes from the

Table 9. --Characteristics of summer burning index at test stations at 4:30 p.m.

National forest and station	Median B.I. class (1945-49)	Percentage of normalcy[1/]		Percentage of persistency[2/]	
		1950	1951	1950	1951
		-------Percent----------			
Mt. Hood:					
Oak Grove R.S.	4	86	74	81	69
Bedford Pt.	4	-	44	-	57
Gifford Pinchot:					
Hemlock R.S.	2	-	82	-	85
Lookout Mt.	3	-	24	-	50
Willamette:					
Salmon Cr. R.S.	4	84	91	93	89
Grasshopper	3	62	-	76	-
Ochoco:					
Wildcat L.O.	3	91	78	96	94
Maury G.S.	4	91	91	87	97
Drake Butte	4	77	48	78	69
Snoqualmie:					
Naches R.S.	3	56	42	55	69
Bald Mt.	3	42	17	51	59
Timberwolf	2	84	72	78	81
Pyramid Pk.	2	40	18	67	73

[1/] Observed B.I. within one B.I. class of the 5-year median B.I. class.

[2/] Observed B.I. within one B.I. class of the previous day's observed B.I. class.

Table 10.--Accuracy of predictions of 4:30 p.m. burning index class

(Percent correct)

Type of day and forecast method	Average, all stations		Average of selected stations (1951)[3]			
	1950[1]	1951[2]	7 peak	5 valley	7 east side[4]	5 west side[5]
A. All days (100 percent)						
Persistency	76	74	69	82	77	70
Median B.I. class	71	57	43	76	52	63
PM prediction[6]	76	76	71	82	76	75
AM prediction[6]	80	77	71	85	77	76
B. B.I. class 5-10 (40 percent)[7]						
Persistency	69	68	60	79	78	53
PM prediction[6]	65	60	55	70	58	64
AM prediction[6]	70	57	52	68	60	55
C. Change days (26 percent)[7]						
PM prediction[6]	61	56	58	53	63	48
AM prediction[6]	62	63	62	65	66	60

[1] Based on 10 stations.
[2] Based on 12 stations.
[3] An analysis according to station location was not made for the 1950 records. The peak and valley stations in the 1951 analysis include east side and west side stations.
[4] East of the summit of the Cascade Range.
[5] West of the summit of the Cascade Range.
[6] Predictions based on FM-a.m. or FM-p.m., each with adapted relative humidity forecast and normalcy wind forecast.
[7] Percentage of all days.

preceding day occurred on approximately one-third of these higher B.I. days. Correct estimates of B.I. were made on only 40 percent of these high B.I. change days.

Results for High B.I. Days

The higher the B.I., the lower the percentage of correct estimates (table 11). Only 37 percent of the class 6 and higher days had correct p.m. predictions of B.I. class as compared with 62 percent for all days class 5 and above. Only 10 percent of the B.I.'s above class 6 were correctly predicted. It is little help to know that 59 percent of the days with B.I. above class 6 involved no change from the preceding day, i.e., a persistency forecast of B.I. would have verified. Persistency is obviously not a satisfactory method of prediction since it cannot predict a change either to or from the high danger condition. Only 1 in 5 of the incorrect evening predictions for class 6 and greater days was corrected by the morning estimate. Morning correction was less likely as B.I. class increased.

Table 11.--Accuracy of p.m. predictions[1/] of B.I. for higher B.I. days for all stations in both test seasons (1950-51)

Type of day and B.I. class	Total days	Correct B.I. predictions	
	Number	Number	Percent
Days with changed B.I.:			
Class 6	48	25	52
Class 7	23	4	17
Class 8	10	0	0
Classes 9 and 10	10	0	0
Days with unchanged B.I.:			
Class 6	77	48	62
Class 7	31	3	10
Class 8	11	1	9
Classes 9 and 10	11	0	0

[1/] Using FM-p.m. with adapted humidity forecast and the 5-year average wind speed.

Causes of B.I. forecast error on high B.I. days.--Incorrect estimates of wind speed were responsible for 65 percent of the wrong predictions of class 6 and higher days, whereas incorrect predictions of fuel moisture accounted for an additional 25 percent. Both wind and fuel moisture were incorrectly predicted for the additional 10 percent of the high B.I.'s. Most of these were unusually windy days. Above class 6, nearly all the high ratings were due to wind. Using persisting wind instead of normal wind for class 6-10 days did not raise accuracy to 50 percent. Accuracy of persisting wind speed for high B.I. days was approximately as high as for any method tested.[7/] Better results would be expected for individual stations for which a wind forecasting aid had been found accurate. Hope for accurate B.I. forecasts for critical days lies with general improvement of forecast accuracy.

[7/] See footnote 2, page 3.

OPERATIONAL CONSIDERATIONS

Accuracy of the various forecasting aids is only one factor considered in evaluating procedures for predicting fire danger. Several operational considerations affect the practicability of using forecasting aids at field stations. Four of these are discussed below: fire-weather forecast, time of optimum use, preparation of forecasting aids, and use of the aids.

Fire-Weather Forecast

This study stems from the assumption that fire-weather area forecasts can be adapted to individual stations by field personnel using simple graphs and tables. These adaptation aids were prepared from past records to show the relation between weather described in the area forecast and actually observed at the station. The success of such aids depends heavily on the accuracy of past and present observations and forecasts and also on a simple and consistent relation between area weather and weather at the station.

The evidence now indicates that the relation between station weather and area weather is not always simple. It varies not only between stations, but also years and apparently weather types. Consequently, there has been great variation in performance of the aids from one station to another. This is due to (1) inadequate exposure of many stations, (2) complex relations between station and area weather not covered by these simple aids, and (3) shortcomings of forecasts, both those used in aid construction and those current ones that are adapted by aids already in service.

Time of Optimum Use of Estimated Burning Index

Since one phase of this study was to consider feasibility of using forecasting aids at field stations, it is appropriate to discuss the time of day when best results may be expected. Time of day, in turn, depends on availability of necessary (1) weather observations; (2) fire-weather forecasts; (3) personnel to make the B. I. prediction from observations, forecasts, and aids; and finally (4) time of administrative need. Although it has long been assumed that earlier availability of forecasts went hand in hand with lower forecast accuracy, such was not found to be the case in this study where only a few hours were involved. The primary consideration of the forest protection agency is to make predictions at a time when they will be most useful. Adjustment of forecast issuance time to correspond to the time of

forecast need would probably result in greater and more uniform forecast use. A questionnaire sent to the ranger districts at the end of the 1950 fire season indicated that the best times for use are before quitting in the afternoon and before roll call in the morning.

Optimum use suggests possible revision of time of forecast release and observation time. Although some slight error in the estimates might result until observations at the new time became available for aid construction, the afternoon observations might be rescheduled for 3:00 or 3:30 p.m. and the morning for 6:30 or 7:00 a.m. In the long run, accuracy of estimates would not be expected to suffer from these changes.

Some protection units may find that morning B.I. predictions for their fire-danger stations will be no more accurate than those made the preceding evening. Where this is true, afternoon fire-weather forecasts, observations, and B.I. predictions should be scheduled for maximum use. Where the W-3 and FM-a.m. give the morning B.I. prediction a significant accuracy advantage, greater attention should be given to optimum use of morning observations and fire-weather forecasts.

Construction of Fire-Danger Forecasting Aids

Mere issuance of instructions and forms was not enough to assure accurate aids. Many aids prepared in the field were grossly incorrect and required complete reconstruction. The following were the most prevalent difficulties, as revealed by the questionnaire and field interviews:

1. Aid preparation required considerable time (up to 30 hours of uninterrupted effort for one station). Extra time is seldom available around a ranger station and it was impossible to do accurate work with frequent interruptions. Therefore, aids were usually prepared outside of office hours.

2. Instructions were highly detailed, offering many possibilities for misinterpretation, particularly if the individual did not understand the reason for each step.

Although the necessary work sheets and final chart forms were furnished to test stations at the beginning of the second season, the same difficulties were encountered. It would appear that

preparation of fire-danger forecasting aids should be closely supervised by someone who understands them.

Use of Fire-Danger Forecasting Aids

Aids were found to be simple once the routine was established on most districts where they were used. There was disagreement, however, over the amount of time required to predict the burning index, varying from 3 to 30 minutes per fire-danger station per day. Prediction without the forecasting aids was thought to take the same amount of time by one district and only half as much by others.

Before the aids were recommended to the field, they were tested under simulated field conditions at the experiment station. It then appeared that the chief problem would be in providing for their handy use. A Summary of Aids form, permitting all aids for a station to be placed on a single sheet, was designed in order to reduce the space required for their display. Some saving of time would have been possible at several districts if a handier system for mounting and displaying the aids had been available.

Personal judgment.--The prediction of fire danger, as proposed by fire control administrators (Introduction), was to be entrusted to the most experienced person at the ranger station on the basis of his judgment of what the general forecast meant for each station. Personal experience and judgment were to have been the only forecast adaptation tools. In the field test of aids, however, judgment was ruled out; prediction by the aid was to be used without revision. On at least one district, personal judgment was added to the objective prediction at a cost of considerable time. A check revealed that the extra effort actually resulted in lower accuracy.

Time required for weather functions.--Fire-danger rating and fire-weather reporting are time-consuming activities at most ranger stations. Weather observation, reporting, record keeping, and predicting the burning index took an average of 1 hour and 32 minutes per district per day on 14 ranger districts in 1950. Of this amount, 9 minutes was the average for burning-index prediction per fire-danger station. On 21 districts where aids were not in use, an average of 1 hour and 10 minutes was required for weather and fire-danger rating. The prediction routine was subsequently simplified by eliminating a complicated running chart (the burning index evaluation record), and by consolidating all aids for each station on a single sheet. In their present form, the aids should permit experienced personnel to predict wind and fuel moisture in less than 2 minutes per station.

Assistance rendered. --Personnel on the test districts stated that they could not have done as satisfactory a job of predicting burning index without the aids. They found, however, that accuracy varied between fire-danger stations.

SUMMARY

A pilot test of fire-danger forecasting aids (charts and tables) was made on 5 ranger districts during the 1950 and 1951 fire seasons to determine (1) feasibility of field preparation and use of the forecasting aids, (2) accuracy of the aids compared with the old prescribed system of assumed persistency, and (3) research needed. The test produced the following results:

1. Preparation of forecasting aids by regular personnel at ranger stations was generally inadequate, due to lack of uninterrupted time, misunderstanding of the principles, and misinterpretation of the instructions.

2. Once correctly completed and set up in handy form, the aids were felt to be quite helpful and sufficiently simple on all districts where they were intensively used. A complete prediction of B.I. requires approximately 2 minutes per station using the procedures tested.

3. Greatest obstacles are inaccurate fire-weather forecasts for both construction and application of the aids, and unsuitability of the aids because of exposure complexities.

4. Although none of the methods tested was reliable for all stations, average accuracy of the most promising procedures was slightly superior to that achieved by the old method of assuming persisting B.I. at all stations.

5. Accuracy varied greatly between stations and from year to year. Comparative accuracy of the aids was determined in relation to other procedures for arriving at an estimate. Both persistency and normalcy forecast scores were used as bases for comparison. Accuracy was determined for all days and separately for days on which the particular weather factor might be considered unusually important. Thus, the aids were specifically tested for ability to predict (a) change from the previous day, (b) nonnormal conditions, and (c) high burning-index situations. The following variations were observed:

Wind speed. Results varied considerably between stations. Averages for all stations showed highest combined verification scores for the important wind events (changes, nonnormal speeds, and high B.I.) were achieved by the spot forecasts and the W-3 aid. Highest verification scores for all days were made by the W-3 aid, the normalcy forecast, and the mean of normalcy and persistency forecasts. Although the aids were more accurate than persistency, they were not as accurate as needed for most stations. Nevertheless, they showed real promise for some stations, and general improvement over previous procedures.

Relative humidity. Persistency forecasts gave the best all-around performance for peak stations, where adapted forecasts predicted about half of the humidity changes. For low-level stations, adapted forecasts were as accurate as persistency; they predicted better than half the changes. Accuracy of the adaptation aid depends greatly on humidity forecasts. There was considerable variation in accuracy between stations.

Fuel moisture. Performance of the fuel moisture aids varied between peak and valley stations. At valley stations, overall accuracy of both a.m. and p.m. predictions was no better than that of persistency forecasts. Slightly less than half the changes were predicted by the p.m. aid and slightly more than half by the a.m. For peak stations, overall a.m. aid accuracy was slightly higher than that of either p.m. aid or persistency. Fuel-moisture changes at peak stations were correctly predicted slightly less than half the time by the p.m. aid and over two-thirds of the time by the a.m. aid. Greater accuracy from the fuel-moisture aids would be expected with improving relative humidity forecasts.

Burning index. Estimates of B.I. using FM aids with adapted relative humidity and normal wind speed were not significantly more accurate than assumed persistency of B.I. at both peak and valley stations. Similar estimates of B.I. for the days on which a change of two or more B.I. classes occurred (25 percent of all days) were more than 50 percent correct, whereas persistency scored 0 percent for this group. B.I. forecasts prepared in the morning were not significantly more accurate than those prepared the previous evening. Stations

for which a successful W-3 wind aid can be constructed, however, will have improved accuracy in the morning, particularly for change days.

CONCLUSION

Use of Aids for Predicting Burning Index

A successful aid must provide forecasts of greater accuracy than either persistency or normalcy forecasts or the mean of the two. An important exception is the aid that correctly predicts significantly more of the important events (i.e., changes and extreme values) than persistency and normalcy forecasts. Even within these guidelines, it is often impossible to differentiate between aids that fulfill the requirements and those that do not. Accuracy of any aid appears to depend on exposure characteristics of the station for which it is prepared, as well as weather during the period in which it is used. Unfortunately, the stations that will benefit most from the aids cannot be determined in advance. Where more than one prediction method seems equally promising, final selection should be based on the following:

1. Purely statistical forecasts such as normalcy or persistency, or the mean of these, are not favored since they can always be considered in addition to a forecast based on current weather indications.

2. A forecast procedure that can predict the development of conditions not already in evidence is preferred over a procedure that can predict only the usual conditions.

3. Accuracy of predictions of important conditions is considered more essential than accuracy of predictions of no change or normal conditions.

These considerations should apply to the selection of aids for each station. Because of station differences, some deviations should be expected from the schedule of aids recommended below. Aids may not operate satisfactorily for some stations for which they are desired.

Some of the procedures recommended have proved more reliable than the old official practice of assuming tomorrow's fire danger would be the same as today's, i.e., persistency. In some cases, improvement over persistency or normalcy may be in quality alone: total accuracy may be similar while an increase in accuracy for

unusual weather conditions is offset by a decrease for usual conditions. The following recommendations are given with the above qualifications:

Wind speed. --For stations exposed to the wind (4:30 p.m. speed averaging at least 6 m.p.h.) use a spot wind forecast wherever available. In the absence of a spot forecast, use a W-2 adaptation of the area forecast in the p.m. and a W-3 forecast in the a.m. In the absence of these aids, use the mean of normal speed and persisting speed. Although overall accuracy for the last procedure is good, we should remember that the only change it can predict is toward normal, i.e., halfway between normal and the previous day's speed.

For stations not exposed to the wind (4:30 p.m. speed averaging less than 6 m.p.h.) consider both normalcy and persistency, possibly using the average of the two for both p.m. and a.m. forecasts. Accuracy may appear high for these stations, but wind may actually approach nonvariability, in which case it may be desirable to select a more exposed site for sampling wind.

Relative humidity. --For peak stations, assume persisting relative humidity from the 4:30 p.m. reading of the preceding day. For valley stations use the correction table for adapting the humidity predicted in the appropriate area forecast. Should spot forecasts of humidity become available, they would probably be the most accurate of available forecasts, particularly for the important events.

Fuel moisture. --For both evening and morning forecasts, use the appropriate FM aid with the humidity forecast recommended above.

Burning index. --Prepare the B.I. from the recommended estimates of wind speed and fuel moisture but keep in mind the possibility of persisting high burning index from the preceding day. Greatest emphasis should be given to the p.m. estimate. The a.m. estimate will sometimes indicate a change missed by the p.m., but is not significantly more accurate. Use of recommended procedures for estimating humidity, fuel moisture, and wind speed should result in higher B.I. accuracies than those found in this test. The improvement would be due to the use of recommended wind speed forecasts, giving higher accuracy for the important days than the normalcy wind forecast used here.

Additional accuracy might be expected from spot humidity forecasts or from a more detailed aid for adapting humidity area forecasts. For satisfactory operation, adaptation aids (W-2 and

relative humidity aids) require a simple and consistent relation between area weather and station weather. Forecasting aids (W-3 and FM aids) need consistent simple relations between indicators and observed weather. Present exposure of many stations rules out the use of either aids or spot forecasts.

The aids recommended above should increase overall B.I. accuracy by 5 to 10 percent. The present method of assumed persistency averages 75-percent accuracy. Greatest improvement is in prediction of important events. Over 60 percent of changes in B.I. would be predicted, compared to none by the persistency forecast.

Alternatives to use of the recommended aids are: (1) Assume persistency of B.I.; (2) use judgment, the area fire-weather forecast, persistency, and the experience of personnel assigned to prepare the B.I. forecast; or (3) do not use prediction, but provide for immediate reporting of significant changes in fire danger so that the fire organization may be adjusted to imminent major changes. Wherever fire danger is considered important, a combination of these alternatives plus the aids is recommended. Where aids are to be constructed, adequate supervision should be provided.

Fire-Weather Forecast

Although fire-weather area forecasts for predicting fire danger at individual stations have their limitations, they are the only source of information on impending changes in fire danger not yet evident. For this reason, the latest forecast should always be at hand and the conditions it foretells considered. If important changes are predicted, fire-danger reporting stations should be alerted. As a guide to the reliability of forecasts, verification records should be kept of predictions of significant changes and important conditions and summarized from time to time. Forecast accuracy should not be left to impression or opinion. The forecast cannot be used intelligently without knowledge of its accuracy.

The fire-weather forecast must be available when needed if it is to be considered in predicting fire danger. Since time of forecast release did not affect accuracy, it should be available at the time of optimum use in order to achieve maximum benefit. Change in fire-danger observation times to 6:30 a.m. and 3 p.m. would facilitate forecasting burning index.

Additional Research Needed

Although the procedures recommended here should bring a slight improvement in the accuracy of predicting fire danger, really adequate accuracy is unlikely without considerable research. Chief possibilities for improvement are tied in with the use of weather forecasts, either through adaptive or direct forecasting for individual stations. The need for research in weather forecasting is limitless, particularly for predictions of major weather changes. Development of techniques for accurate spot forecasts for key fire-weather stations should also have high priority.

The following studies are suggested as prerequisite to optimum application of forecasts to fire-danger rating. First, we may need new standards for the location and exposure of fire-danger stations. The objective would be to select only stations that sample weather related in a simple way to the general weather pattern, as well as representative of the surrounding fire-control area. The present study indicates that many fire-danger stations do not possess these qualifications.

The second need is for better use of observations and predictions for these stations. Tools are needed so that fire-control personnel may determine from weather at key stations, the fire danger throughout the area. Also needed are more adequate methods of describing wind and humidity for an extensive mountainous area.

As forecasts and exposures of fire-weather stations improve through research, so also will the opportunities for fire-danger forecasting aids of the types tested. Those that differentiate between weather types and station exposure characteristics will be most promising but may not be sufficiently simple for practical use in the field. Although research may be expected to produce more accurate predictions of fire danger, this is likely to be at the expense of simplicity in both observational and forecasting procedures.